WORKING PAPER
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

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Working Paper #1998-88

March 1988

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MIT and NBER and Harvard University and NBER respectively. We wish to thank Olivier Blanchard, Marc Bils, Tim Bresnahan, Dennis Carlton, Bob Hall, and Louise Sheiner for helpful discussions, Bob Gordon for generously sharing his data on man hours and output with us and Louise Sheiner for able research assistance. We also acknowledge the support of the NSF and the Sloan Foundation.

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Abstract

Hall has pointed out that, when there is perfect competition and price flexibility, labor hoarding alone will not induce the Solow residual measured using labor's share in revenues to be procyclical. We show that, even with perfect competition, a small amount of price rigidity - we assume firms must set price slightly before the level of demand becomes known - makes the extent of procyclical productivity depend mainly on the extent of labor hoarding. We show that indeed, whether productivity is measured via the Solow method using labor's share in revenues or using other methods, it tends to be more procyclical in industries and in nations where labor hoarding is more important.

Introduction

The phenomenon of procyclical physical productivity in the face of wars and other demand shocks has long been recognized. Businessmen have always appreciated the benefits of cyclical expansion; they are able to use their capacity more fully and so their costs per-unit fall. Countless empirical studies have demonstrated that increases in labor input over the business cycle are associated with more than proportional increases in output.[1] The appropriate interpretation of the procyclicality of various productivity measures has long been a matter of debate among economists and has attracted renewed interest since the work of Hall (1987, 1988).

This paper seeks to rehabilitate both theoretically and empirically an idea that has gone somewhat out of fashion--the notion that procyclical productivity regardless of how measured arises because it is costly for firms to adjust their capacity and so capacity utilization (both in terms of labor and capital) fluctuates over the business cycle. We believe that variations in the extent to which productivity is procyclical have more to do with differences in the extent of labor hoarding than with market power. Developing this line of argument also leads us to a perspective on the reasons why price often seems to exceed marginal cost in US industry which is somewhat different from Hall's.

At least since Solow (1964), economists have traditionally given two related explanations for procyclical movements in output per man-hour. The first holds that firms are generally operating in a region of their cost curves where there are increasing returns to scale

because firms must incur some fixed costs in the form of "overhead" labor in order to operate at all. This interpretation of procyclical productivity suggests that barriers to entry in the form of increasing returns to scale are endemic and anything like perfect competition is inherently impossible.

The second "labor hoarding" explanation for procyclical productivity holds that labor input is difficult or costly to change in the short run. The costs of varying labor input stem not only from the costs of hiring and firing workers but also because changing the number of workers employed in a firm requires organizational changes that take time. If adjusting labor input is costly, firms will "hoard" labor during recessions so that output will decline more than proportionally with labor input. In booms, as previously hoarded labor comes to be utilized fully, productivity will increase. This story unlike the preceding one, is logically consistent with firms having constant returns to scale in the long run and pricing competitively. Thus distinguishing the stories is of some importance.

As Solow (1964) noted, both of these explanations for procyclical movements in output per man-hour imply that marginal costs should be very low during recessions. If firms price competitively, one would therefore expect to see very low prices during recessions. If there are increasing returns to scale price would be very low, except perhaps in booms when firms are operating at capacity. Similarly if output is low and there is labor hoarding, marginal cost (and thus price on the naive competitive view) must be very low since the firm has labor which is kept employed while it is essentially idle. That prices fail to behave in this manner is apparent not only from

macroeconomic data but also from everyday experience.[2] Airlines charge high prices for seats in half empty planes. Hotels with vacant rooms charge much more than the cost of cleaning a room for a night's stay. Bookstores charge their customers twice what they pay for even best selling titles.

Hence, either explanation for procylical productivity must be complemented by resolution of the pricing puzzle of why price seems to far exceed marginal cost when there is excess capacity as in recessions. The pricing puzzle has itself been the subject of a voluminous literature. Two distinct but not mutually exclusive explanations for the excess of prices over marginal costs during recessions have been suggested. The first (which complements nicely the view that there are increasing returns to scale) is that price setters possess a great deal of market power: firms either produce goods for which there are no good substitutes, do not effectively compete through prices, or both.[3].

The second explanation for the pricing puzzle is that prices are in some sense rigid so that they remain at the high levels of the boom even in the slump.[4] In the presence of price rigidity, prices do not rise sufficiently in high demand states to cover the costs of capacity. Thus, some of these capacity costs are covered in low demand states and, then, price exceeds marginal cost. This basic idea is pursued at length below.

The foregoing discussion can be summarized with the help of figure 1 which has the two puzzles on the two axes, each accompanied by two explanations. We have inserted Hall's name in the increasing returns-monopoly power combination because in Hall (1988) he

explicitly embraces the idea of monopoly power and rejects price rigidity as the explanation for the behavior of total factor productivity. In his 1987 paper he also notes that profitability in US industry is low: the rate of return on physical capital is not very different from the rate of return required by investors. Taking as given his 1988 estimates for the extent of monopoly power, constant returns to scale cannot be reconciled with US data. He concludes that there are always increasing returns: either firms must incur large fixed costs to operate or firms have much excess capacity. Therefore, labor hoarding is not itself the major determinant of the extent of procyclical productivity.[5]

Figure 1

The Puzzles and their Interpretations

Puzzles	Physical output per man-hour procyclical		
	Explanations	Increasing returns	Labor hoarding/ Constant returns
Price above marginal cost	Monopoly power	Hall	
below capacity	Price rigidity		Rotemberg Summers

In figure 1 we have associated our own names with the opposite labor hoarding-price rigidity combination reflecting the emphasis of the current paper. This is not to deny any role for

monopoly power or increasing returns in accounting for cyclical productivity and pricing patterns. Rather we suspect that labor hoarding combined with inflexibilities in pricing are dominant determinants of the cyclical behavior of various productivity measures. We buttress this argument providing some preliminary empirical evidence suggesting that differences in the costs of adjusting labor are very important in accounting for variations in the cyclicality of productivity.

Section I demonstrates the basic idea that, if prices are rigid, they will be below marginal cost in low demand states and, as a result, productivity will appear procyclical as long firms hoard labor. Section II extends these results to the case of "micro" price rigidity where firms know the distribution of possible demand realizations (which depends on the business cycle), but not the actual realization before they set their price. It turns out that price rigidity due to "micro" uncertainty about the state of demand is sufficient to account for the observed cyclical behavior of productivity.

Section III informally reviews some empirical evidence bearing on the relative importance of labor hoarding-price rigidity and monopoly power-increasing returns to scale. We argue that the former story provides the most plausible account of two major stylized facts, that productivity is more procyclical in industries where a larger fraction of employment consists of nonproduction workers and the observation that productivity is far more procyclical in Japan than in the United States by any available measure. Further evidence supporting our view comes

from an examination of the dynamic response of productivity to changes in employment. Section V concludes.

I. Keynesian Price Rigidity

This section demonstrates our two fundamental points--that price rigidity can explain why prices appear to exceed marginal cost and that price rigidity can rationalize the belief that labor hoarding is responsible for the procylicality of productivity.

Consider an industry in which output Q cannot exceed installed capacity Y. Adjustment is so costly that capacity is not changed at all when demand fluctuates. Some of the costs of capacity are undoubtedly labor costs and, for illustrative purposes, we abstract from any other capacity costs. We thus assume that to produce Q units an amount of labor L equal to (cQ+vY) must be employed. So, an amount of labor vY is hoarded even when output is zero. This cost function implies that in the long run, if the firm operates at capacity, its costs are independent of its scale. All prices are in units of labor (or the wage is one).

Let demand be either high or low. Demand and capacity are such that, when demand is low, less than Y is demanded at a price equal to marginal cost c; however when demand is high more than Y is demanded at a price of c. The competitive equilibrium for this industry would have a price of c when demand is low and a price such that Y is demanded when demand is high.

Suppose that the business cycle is the alternation of low and

high demand. Then, output per man hour, Q/L, whose movements in this model without capital correspond to the Solow residual obtained using labor's share in costs, is clearly procyclical. When going from low demand to high demand dQ/dL equals 1/c while Q/L equals instead 1/(c+Yv/Q). Therefore, (dQ/Q)/(dL/L) is larger than one. This captures the basic insight that while a few more flight attendants work at peak hours than at off peak hours on the Eastern Air Shuttle, productivity measured as passengers carried per employee is much larger at peak hours. In the same way, an extra customer walking into a store increases the productivity of its employees. Examples like this probably provide the basis for the widespread attribution of procyclical productivity to labor hoarding.

However as Hall (1988) stresses, if firms price competitively total factor productivity, or the Solow residual residual using labor's share in revenue, will not increase in this situation. In particular, the change in total factor productivity equals (1/PQ)[PdQ-dL] and rises when revenues (evaluated at base prices) rise by more than labor input. When going from low demand to high demand this expression is clearly zero if price P equals c as it does in the competitive equilibrium. The increased output is valued so little that productivity does not increase. He thus suggests that monopoly power, which raises P above c, is needed to explain pricing behavior. As a result he is led to abandon the notion that labor hoarding can explain the observed behavior of productivity.

Hall's argument breaks down if prices are inflexible.

Consider the extreme case where price is independent of demand. Such price rigidity necessarily implies that price exceeds c, for otherwise firms could never recover their capacity costs. Any such excess of P over c implies that (1/PQ)[PdQ-dL] increases when demand rises. Thus with price rigidity the extra units that are produced are valued highly, leading to an increase in measured productivity when demand rises.

Price rigidity together with the requirement that firms cover their capacity costs and market power can thus generate very similar implications for the behavior of total factor productivity. Why then does Hall (1987) deny the the role of price rigidity with an example in which it fails to induce procyclical productivity? The crucial difference between Hall's example and ours is that he assumes that firms with rigid prices always supply what is demanded at the rigid price, even when this price is less than their marginal cost. When demand goes up, some of demand is met by incurring very high marginal costs; the provision of these expensive units tends to depress productivity. In our example, by contrast, firms whose prices are rigid follow the profit maximizing strategy of rationing consumers in high demand states when the marginal revenue from meeting their demand is less than the marginal cost.

There is substantial debate over the extent of price rigidity over the business cycle. The evidence surveyed in Rotemberg (1987) suggests that some prices do indeed remain constant for several years lending credence to the possibilility that price rigidity accounts for the appearance of procyclical productivity.

Discussions of the inflation process inevitably emphasize the role of shortages in precipitating inflation. Moreover, delivery lags, which can be viewed as a form of rationing insofar customers are not getting the product they really want -namely instant delivery- at the posted price, lengthen during booms. This suggests that at least some rationing is observed at cyclical peaks. Okun (1981) feels that at strong cyclical peaks, shortages have an important detrimental impact on resource allocation when he writes, "In boom periods, many specific shortages last sufficiently long...that buyers make behavioral adjustments...(though) shortage phenomena are widespread only in periods...like 1966 and 1973." (p.277).

While price rigidity over the business cycle may or may not be important, we demonstrate in the next two sections that price rigidity of a more plausible sort, is sufficient to generate procyclicality in productivity and pricing above marginal costs, even in the absence of monopoly power.

II. Micro Price Rigidity

Within any business cycle phase there are many different states of demand. Think of a movie theater that does not know whether it is showing a hit or a toy manufacturer who doesn't know whether his new offering will be the next Cabbage Patch Doll or will flop completely. If the Walrasian auctioneer cleared the market every second, prices would fluctuate with the state of demand within cyclical phases. We refer to departures from perfect peak load pricing which arise because firms must set their

price before the state of demand is known, or are unable to continuously vary prices as "micro" price rigidity.[6] As we discuss below, this is a strictly weaker and more plausible form of price rigidity than that considered in the previous section because here prices are allowed to vary with aggregate demand.

The Prescott Model

Consider a setup due to Prescott (1975) in which demand for a homogeneous product is uncertain and competitive firms set prices (i.e. write price tags) before the state of demand is revealed. Customers always buy the cheap items first. They turn to high priced items only when the cheaper ones are exhausted.[7] In equilibrium, some goods will be priced low and will sell out most of the time, while others will have a high price and so only will be sold in large demand states. While it will be convenient in what follows to think of different firms as choosing different prices, this is in no way necessary. A given firm may charge low prices to its first few customers, and then higher to subsequent customers, as is common in the post-deregulation US airline industry.

Let consumers' reservation price, which does not depend on the state of demand, equal r. What varies across states is the amount Q they want to buy at this reservation price, in state s they are willing to purchase g(s) where g is an increasing function.[8] The states of nature s can be taken, without loss of generality, to be uniformly distributed between zero and one.

There are a large number of potential firms. Risk neutral firms choose capacity first, then quote prices and, only then, are the states of demand realized so that sales take place.

In equilibrium there are a continuum of producing firms. For ease of presentation we think of each as charging only one price. To describe this equilibrium we let s(P) be the state such that for all states equal to or higher than s(P) a firm charging P sells up to capacity. This definition implies both that an amount g(s(P)) is supplied by firms charging P or less and that firms charging P can expect to sell all that they can produce with probability (1-s(P)). Therefore the expected unit profits of a firm charging P are:

$$[1 - s(P)][P - c] - v. \qquad (1)$$

In equilibrium, firms must break even. If losses are realized by a firm charging P so that the expression (1) is negative, the firms would prefer not to build capacity. If instead, the expression in (1) is positive, more firms would build capacity and charge P. A firm contemplating such entry can neglect the effect of its entry on the probability of selling because it can enter supplying only an infinitesimal amount. Therefore in equilibrium the expression (1) must be zero for all prices actually charged. Of course, no price below (c+v) is charged for that would lead to losses nor is a price above r charged for there would be no demand at this price.[9]

To complete the demonstration that this is an equilibrium we now show that deviations at the pricing stage are unprofitable. Obviously nothing is gained by charging less that c+v or more than

r. For prices between c+v and r the proposed equilibrium in which (1) equals zero has all firms making equal profits. So unless a deviating firm affects the probability of selling at any particular price, firms are indifferent to the price they charge. Yet, the fact that there are a continuum of firms ensures that this distribution is essentially unaffected by single firm deviations.

The equilibrium requirement that (1) be zero for all prices charged implies that the price charged by each firm equals its average cost. So this model is consistent with the claim of Hall and Hitch (1939) that firms charge "full average" cost. It is also consistent with the notion that price equals "long run" marginal cost where long run marginal cost is appropriately defined to recognize that the firm will not always be able to make use of its capacity.

From (1) it is apparent that capacity which is only utilized in the highest state of demand will only be installed if the price paid in that state is infinite. If instead, the reservation price r is finite, it will be charged to all states above s^* where s^* is such that:[10]

$$s^* = (r-c-v)/(r-c). \tag{2}$$

Rationality on the part of firms requires that the price be r for any states where demand is not fully met. By the same token, if r is charged to customers in states lower than those in which industry capacity is fully used up, a firm charging r could increase its profits by undercutting the price slightly. Therefore s^* is the highest state in which demand is fully met.

So, if total marginal cost $(c+v)$ is kept constant while the level of congealed costs v is increased, s^* falls, i.e. the number of states whose demand is not fully met goes up.

Demand Shocks and Measured Productivity

We now consider the effects on various productivity measures of an increase in aggregate demand which is accompanied by price changes. Suppose in particular that the maximum consumers are willing to buy at r is now given by

$$Q = g(s) + u$$

so that aggregate demand increases, which raise u, raise demand by the same amount in each state. In this model the increased demand that results from an infinitesimal increase in u will be met for all states below s^* whether prices change in response to the increased demand or not. The reason is that, since r exceeds c, rationing by high priced firms is never optimal so the amount firms are willing to sell is always equal to $g(s^*)$.

If firms are free to readjust prices the equilibrium equates the unit profits of firms charging different prices. Now these unit profits given by (1) are equated to a number which differs from zero. This number can be computed as follows. Let $s'(u)$ be the highest state for which demand is fully met so that $g(s'(u))$ equals $g(s^*)-u$. Then by the earlier arguments r is charged by the firms who sell only when the state equals or exceeds s'. These firms earn unit profits equal to $(s^*-s'(u))(r-c)$ and these must also be the unit profits of firms charging other prices.

The increased labor costs (dL) associated with the increased sales from an infinitesimal increase in u, du, are given by cs^*du. Let R be the usual index of real output obtained by valuing outputs of different goods (namely those supplied in different states) at the initial prices. Then the Solow residual is procyclical if dR/dL is greater than one so that the value of output increases more than the value of labor input. The change in R is:

$$dR = du\int_0^{s^*} P(s)ds = [(c-k)\log(1-s^*) + cs^*]du$$

where P(s) is the price charged initially by firms who sell in states greater than or equal to s and can be obtained by inverting (1), k equals total marginal cost (c+v), while the second equality is obtained by using (1). Thus the ratio dR/dL is given by:

$$dR/dL = 1 - (k-c)\log(1-s^*)/cs^*$$

which exceeds one. So total factor productivity is clearly procyclical.

Consider now the effect on R/L, the ratio of the value of output (at base prices) to man hours. Since there is free entry and no fixed costs, the initial value of R/L is one. So changes in R/L are given by dR/dL and are R/L is also procyclical.

Moreover, assuming k is constant and differentiating with respect to c:

$$d[dR/dL]/dc = (k-c)\log(1-s^*)/(rs^*(r-c)) + [(k/c)\log(1-s^*)/s^* + 1]/c.$$

The term in brackets is negative both because (k/c) exceeds one and because $\log(1-s^*)/s^*$ is smaller than minus one for s^*

between zero and one. Thus, dR/dL declines when c rises. This means that, as costs become less congealed, as labor becomes more variable, the extent of procyclical productivity declines. We return to this observation below in Section IV as we try to distinguish empirically between different theories.

The Importance of Rationing

Notice that the model considered in this section exhibits the rationing that our previous analysis suggests is necessary to overturn Hall's results. With many different prices charged by different firms some firms are always running out. Individuals are rationed in the sense that they are unable to buy goods in the good terms that they have been obtained by others and must turn to more expensive suppliers. It is important to stress that this form of rationing (which is all that is required) is very mild and widespread. It is only necessary that not all individuals suceed in buying items when they are on sale. Such "limited quantities" sales can be seen advertized in any Sunday newspaper.

The extent of rationing is actually much greater than this type of example suggests once it is recognized that in many settings consumers who buy first get a higher quality product, which is tantamount to paying a lower price. Take the case of a movie theatre. Some seats are more desirable than others and they fill up first. Late comers are rationed in that they must content themselves with worse seats. So while the price tag on all seats of a given showing is the same, the price per unit of intrinsic

quality is lower for the good seats which are grabbed first. Similarly, in an airplane, aisle and window seats go first.

While rationing can take these very mild forms in the model we have described, the more traditional form of rationing - customers actually unable to buy the good they wish at any price- would emerge if reservation prices rose when demand rose (or alternatively if demand curves sloped down throughout). Does this form of rationing actually take place? At an informal level, seats on airplanes are unavailable at the last minute on holiday weekends, that rooms in hotels are unavailable during graduation week and that not all customers get in when hit movies have their first run. It is generally felt that those who do their Christmas shopping early have access to a better selection. In the case of industrial goods, early comers get relatively flexible delivery terms while later customers may have to wait longer. Carlton (1987) gives several examples of such rationing between firms which he, like us, interprets as due to the rigidity of prices.

More quantitative evidence is presented in Progressive Grocer (1968) which reports that, on average, 12.2% of major brand items carried by supermarkets are out-of-stock at any point in time. The Nielsen study which forms the basis for this calculation also indicates that 30 percent of customers at the typical store are unable to purchase all the items on their shopping lists. It also reports that the rate of stockouts varies significantly over the course of the week. A Chicago study found that 17% of frozen food items were not available to consumers on Monday and that 12% were missing on Wednesday and 11% on Friday. Interestingly, while the

article devotes considerable attention to the problem of minimizing stockouts, the idea of raising prices on items that are in short supply is never mentioned. The article also mentions that one fifth of the individuals who find the item they want missing refuse to substitute.

The model developed in this section demonstrates that procyclical productivity and the appearance of price in excess of marginal cost when demand is low can arise in a perfectly competitive setting. We want to stress that these results follow merely from the need of firms with rigid prices to recover some of their capacity costs in low states of demand and does not depend on the precise formulation of our model. To provide some evidence for the robustness of our logic we present in the Appendix a model in which products are differentiated and there is monopolistic competition. That model lacks the not always realistic implication of te Prescott model that different firms charge different prices for exactly the same good.

In the model of the Appendix price exceeds marginal cost even with flexible prices so productivity using labor's share in revenues is always procyclical. Nonetheless we demonstrate that this measure of productivity becomes even more procyclical when prices are rigid across states of nature within a business cycle phase. This model alaso allows us to demonstrate a variant of the point in Hall (1987). We show that the Solow residual measured using labor's share in cost (which in our model corresponds to the naive measure of labor productivity) is not procyclical with flexible prices even with labor hoarding and monopoly power. On

the other hand and in line with the results presented above, inflexible prices make this measure of productivity more procyclical the more important is the hoarding of labor.

III Empirical Evidence

In this section we discuss how various measurements of the behavior of productivity militate in favor of our interpretation of procyclical productivity. We consider in turn the behavior of productivity across industries, across nations, the response of productivity to changes in different factors and the dynamic behavior of productivity when output changes.

Productivity across Industries

The relative importance of the two theories we have contrasted can be gauged by seeing whether, across industries, the procyclicality of productivity is related more to indicators of market power or to indicators of labor hoarding. One indicator of labor hoarding in an industry is the extent to which it employs non-production workers. Comparing industries with different fractions of nonproduction workers sheds light on the role of labor hoarding because employment of nonproduction workers varies much less; these workers tend to be hoarded in recessions. A regression of Hall's (1986) measures of the procycality of productivity for 18 2-digit manufacturing industries on their ratio of nonproduction workers to employment in 1960 gives:

$$\text{Procyc} = \underset{(.37)}{.96} + \underset{(1.51)}{3.42}*\text{nonprod/emp} \qquad R^2=.24$$

where standard errors are in parenthesis. Figure 2 presents a plot of our data (with the SIC code for the two digit industry next to each point) as well as of the fitted line obtained from our regression.

Adding the average 4-firm concentration ratio to these regressions gives:

$$\text{Procyc} = \underset{(.47)}{.94} + \underset{(1.61)}{3.39}*\text{nonprod/emp} + \underset{(.92)}{.06}*C4 \qquad R^2=.24$$

In contrast to what one would expect under the market power view, the indicator of such power C4 has essentially nothing to do with the procyclicality of productivity and does not affect the importance of the ratio of nonproduction workers to employment. The lack of importance of concentration is confirmed by Blanchard (1987) and by the much larger study of Domowitz, Hubbard and Petersen (1986).

Productivity across Nations

Table 1 illustrates that Solow residual measured relative to revenues is more procyclical in Japan than in the United States.[11] The difference between the two sets of estimates is both economically and statistically significant. These regressions are obtained by using output growth in the US and Europe as instruments to obtain the estimates for Japan while output growth in the US and Europe are used as instruments to obtain estimates for the US. While it is conceivable that this result obtains

because Japan is more monopolistic than the US, it is easy to interpret this finding in light of the labor hoarding-rigid prices box. Given the dependence of Japanese manufacturing on export markets it is implausible that it is far more heavily monopolized than American manufacturing. On the other hand, institutional differences promoting lifetime employment, and pressuring firms to retain workers during recessions are widely recognized.

Consider again the labor hoarding-rigid price box. According to this set of explanations, not only total factor productivity, but also output per man-hour should be more procyclical in countries such as Japan where labor is more fixed in the short run. The fact that Japan's output per man-hour is indeed more procyclical is well known and can be seen in table 2.

Note that the preceding section demonstrates that labor hoarding per se cannot account for the cyclicality of output per man hour unless there are rigid prices. Thus the fact that output per man-hour in Japan is more procyclical would have to be attributed to greater increasing returns to scale if the assumption of price flexibility is maintained. If, instead, micro price rigidity is recognized, Japan's productivity perfomance on both measures can be linked to the institutions that lead to greater labor hoarding.

Productivity Movements with Several Factors

When several factors of production are analized at once, the market power explanation for procyclical productivity has an

additional testable implication. Any increase in inputs should be accompanied by the same increase in productivity once due account is taken of their respective share in revenue. An instrumental variable regression of output growth on the rates of growth of inputs multiplied by their respective factor shares would give the same coefficient on each input and this coefficient could be interpreted as the ratio of price to marginal cost.

Using data on various inputs and imposing the equality of these coefficients leads Domowitz, Hubbard and Peterson (1988) to estimates of the ratio of price to marginal cost which differ from Hall's (who concentrates on labor input alone). Yet, Griliches (1987) shows that the data reject the equality of these coefficients. While increases in energy and materials do not raise total factor productivity, increases in labor do. While we do not present a fully worked out model in which different inputs vary over time, the Griliches findings seem at least broadly consistent with our story. According to this story, prices exceed marginal cost (which makes productivity procyclical) only because the full cost of the quasi-fixed factors is incorporated in the price even in the slump.

Dynamic Response of Productivity to Demand

The response of productivity over time to changes in output suggests that procyclical physical productivity is due at least to some extent to labor hoarding and that increasing returns to scale cannot be the whole story. In the two studies where output data

are measured in physical units (Hultgren (1960) and Fair (1969)) there is evidence that as output expands productivity first rises and then, at least for many industries, falls. This is consistent with the idea that it takes time to change the quasi-fixed labor inputs. On the other hand it would seem that with pure increasing returns to scale, productivity would keep rising (as it does for some individual industries). This would not necessarily be true if entry by new firms occurred in response to the expansion but the amount of time it takes for productivity to start falling makes this particular explanation difficult to believe.

More evidence along these lines is obtained if it is accepted that price is independent of state so that measures of aggregate industry output actually correspond to measures of physical units. Both Sims (1974) and Gordon (1979) use aggregate data on manufacturing output and labor input to describe the time series properties of conventional labor productivity. They conclude that expansions raise productivity but that productivity tends to revert towards its normal level. Gordon (1979), in particular, shows that this reversion is more prevalent at the end of expansions.

Figure 3 use monthly data on US manufacturing over the period 1962 to 1985 to evaluate the response of productivity to demand impulses as proxied either by increases in manhours or output.[12] The result which appear robust to whether the equation is estimated using first differences or levels, confirm earlier results suggesting that productivity rises and then falls following demand impulses as would be expected if labor was

hoarded.

IV. Conclusions

The results in this paper suggest that traditional analyses emphasizing the costs of adjusting capacity and labor hoarding capture important aspects of productivity behavior. In conjunction with plausible degrees of price rigidity, labor hoarding can account for the observed cyclical behavior of various productivity measures.

At this point it is difficult to gauge precisely the relative importance of the labor hoarding-price rigidity story that we have stressed and the increasing returns-monopoly power story stressed by Hall. In future research it would be valuable to extend our comparison of the United States and Japan to embrace other countries. The variables constructed by Lazear (1987) in his study of employment security rules might be useful proxies for the costs of labor adjustment. Measuring monopoly power is likely to be more difficult. One plausible strategy would involve studying the cyclicality of productivity in different countries for industries that produce for world markets. This would at least crudely hold the degree of monopoly power constant.

A different approach would involve more detailed investigation of the dynamics of productivity movements. Any satisfactory resolution of the productivity and pricing paradoxes should account for the dynamic pattern of productivity's response to labor input--rising sharply then falling as labor input

increases. This seems more naturally consistent with the labor hoarding view, though rationalizations involving increasing returns are probably possible.

FOOTNOTES

1 Two studies that use physical output data are Hultgren (1960) and Fair (1969). Many other studies use more aggregated output figures which are obtained using prices to obtain value indices. The analysis of procyclical movements in these somewhat different measures of productivity is somewhat more delicate as we show below.

2 That marginal cost, on the other hand, is low in recessions has also been documented by Fay and Medoff (1985).

3 This view was clearly espoused by Robinson (1932) when she wrote: "There are two factors which will lead to a rise in price when demand falls. If marginal costs are falling, the reduction in output (due to the fall in demand) will raise marginal cost...And if demand becomes less elastic as it falls there will be a tendency for the price to be raised"

4 Modelling prices as markups on standard or normal unit labor costs rather than on current labor costs is a long tradition in work on price equations. An extreme version of the rigid price view is expressed by Hall and Hitch (1939) who after conducting interviews with thirty eight entrepreneurs on price policy concluded that "an overwhelming majority...thought a price based on full average cost was the "right" price".

5 Hall (1988) recognizes that his use of the procyclicality of the Solow residual to measure the excess of price over marginal cost can be biased towards "rejecting competition" in the presence of labor hoarding for two reasons. First, with labor hoarding, output may fall less in recessions than measured in the NIPA if what workers produce in the slump is some form of unmeasured investment. Second, with labor hoarding, the fall in actual labor input in the recession may be larger than the measured fall in man-hours of work. For a variety of reasons he dismisses the empirical importance of these measurement errors.

6 This is the kind of price rigidity commonly employed in the literature on inventories. See Kahn (1987) for example.

7 For a related model in which goods are perfect substitutes before the customer chooses which firm to purchase from but where purchasing from a second firm is impossible if the chosen firm has run out see Carlton (1978).

8 The assumption of a fixed reservation price that does not vary is not necessary for our results about the behavior of productivity. It does simplify the exposition and as stressed by Prescott allows the market optimum to be attained even when prices must be set before demand is revealed.

9 This model is formally almost identical to Butters (1977). In the

Butters model, unit production costs equal c whereas v corresponds to the cost of sending an ad to a single customer. Equilibrium then requires that an expression such as (1) be zero for prices between c+v and the reservation price r where [1-s(P)] is the equilibrium probability that an ad of price P will be the ad with the lowest price received by the customer and will thus lead to a sale.

10 Equation (2) also gives the maximum state which is fully served with flexible prices. This fact, which lies behind Prescott's (1975) demonstration that capacity is efficiently chosen even with rigid prices, can be understood as follows. With flexible prices the price is c unless demand exceeds capacity; at that point the price jumps to r. The probability $(1-s^*)$ of receiving r must be such that capacity costs v are covered. This is what (2) requires.

11 The regressions in table 1 are estimated using data on manufacturing output, labor input and labor compensation provided by Robert Gordon and described in Gordon (1987).

12 The figures are obtained by first running regressions of productivity either on man-hours or on output. Then, we simulate how productivity would respond to a permanent change in either man-hours or output.

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TABLE 1
PROCYCLICAL MOVEMENTS OF TOTAL FACTOR PRODUCTIVITY IN MANUFACTURING

a) Regressions of output growth on labor share times man-hour growth

Specification	1	2	3	4	5
Sample period:	62-84	62-84	62-84	62-72	73-84
Additional Regressors:		trend	dum73		
US	1.70 (.24)	1.78 (.29)	1.85 (.31)	3.48 (3.01)	1.68 (.22)
Japan	3.75 (.82)	3.49 (.86)	3.13 (.80)	-10.05 (25.71)	3.21 (.44)

b) Regression of labor share times man-hour growth on output growth

Specification	1	2	3	4	5
Sample period:	62-84	62-84	62-84	62-72	73-84
Additional Regressors:		trend	dum73		
US	.59 (.08)	.63 (.10)	.66 (.11)	.24 (.25)	.57 (.07)
Japan	.20 (.05)	.23 (.05)	.21 (.05)	-.04 (.14)	.30 (.04)

Note: Dum73 is a variable which takes the value of zero before 1973 and one thereafter. Data are provided by Robert Gordon and are described in Gordon (1987).

TABLE 2
PROCYCLICAL MOVEMENTS OF OUTPUT PER MAN HOUR IN MANUFACTURING

a) Regressions of output growth on man-hour growth

Specification	1	2	3	4	5
Sample period:	62-84	62-84	62-84	62-72	73-84
Additional Regressors:		trend	dum73		
US	1.20 (.17)	1.25 (.21)	1.30 (.22)	2.40 (2.1)	1.19 (.15)
Japan	1.92 (.39)	1.80 (.42)	1.61 (.40)	-3.82 (10.1)	1.67 (.21)

b) Regressions of man-hour growth on output growth

Specification	1	2	3	4	5
Sample period:	62-84	62-84	62-84	62-72	73-84
Additional Regressors:		trend	dum73		
US	.83 (.12)	.90 (.15)	.94 (.16)	.36 (.36)	.81 (.10)
Japan	.41 (.09)	.43 (.10)	.40 (.10)	-.10 (.33)	.59 (.07)

Note: Dum73 is a variable which takes the value of zero before 1973 and one thereafter. Data are provided by Robert Gordon and are described in Gordon (1987).

Figure 2

The Extent of Procyclical Productivity

and Nonproduction Workers/Employment

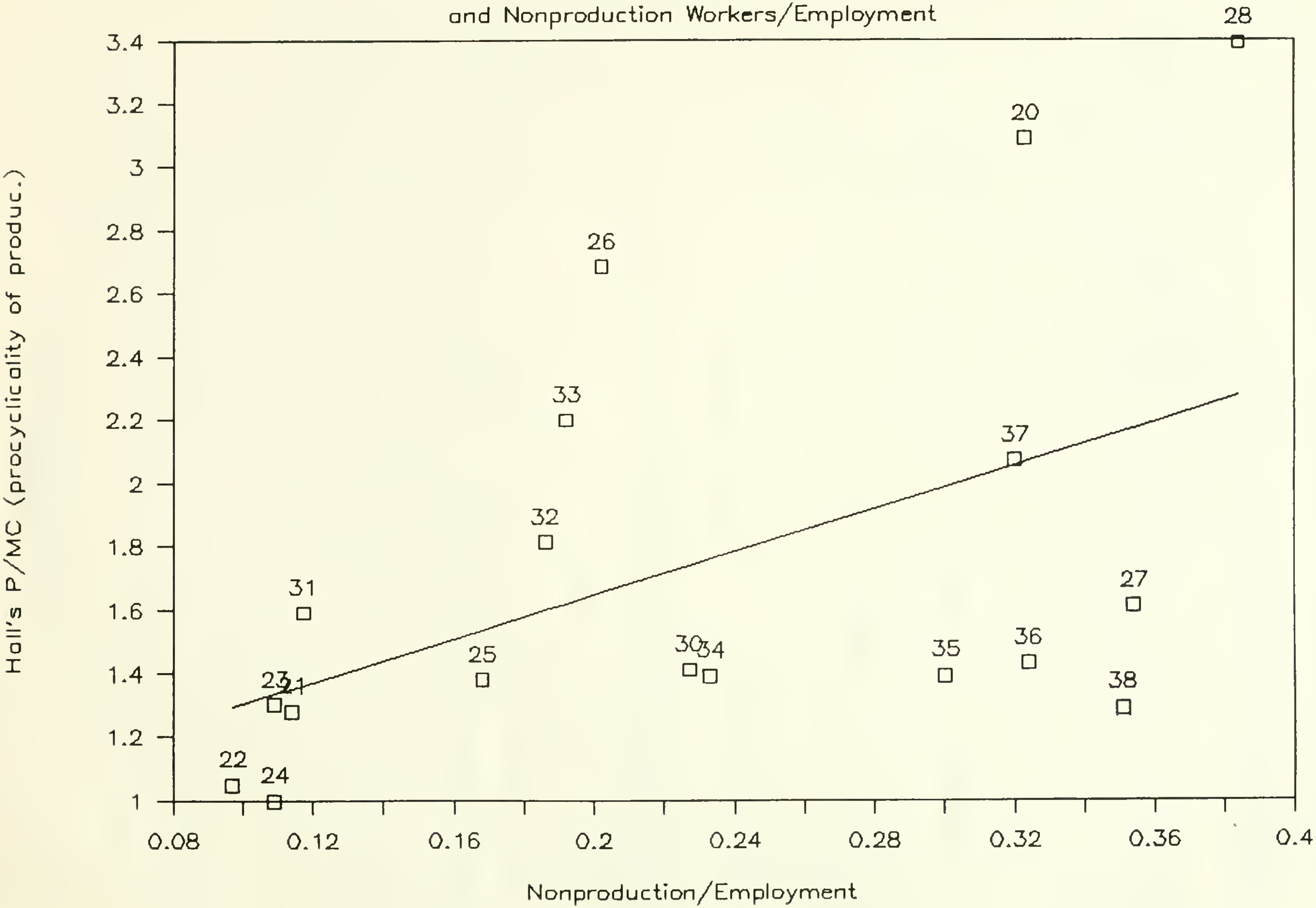
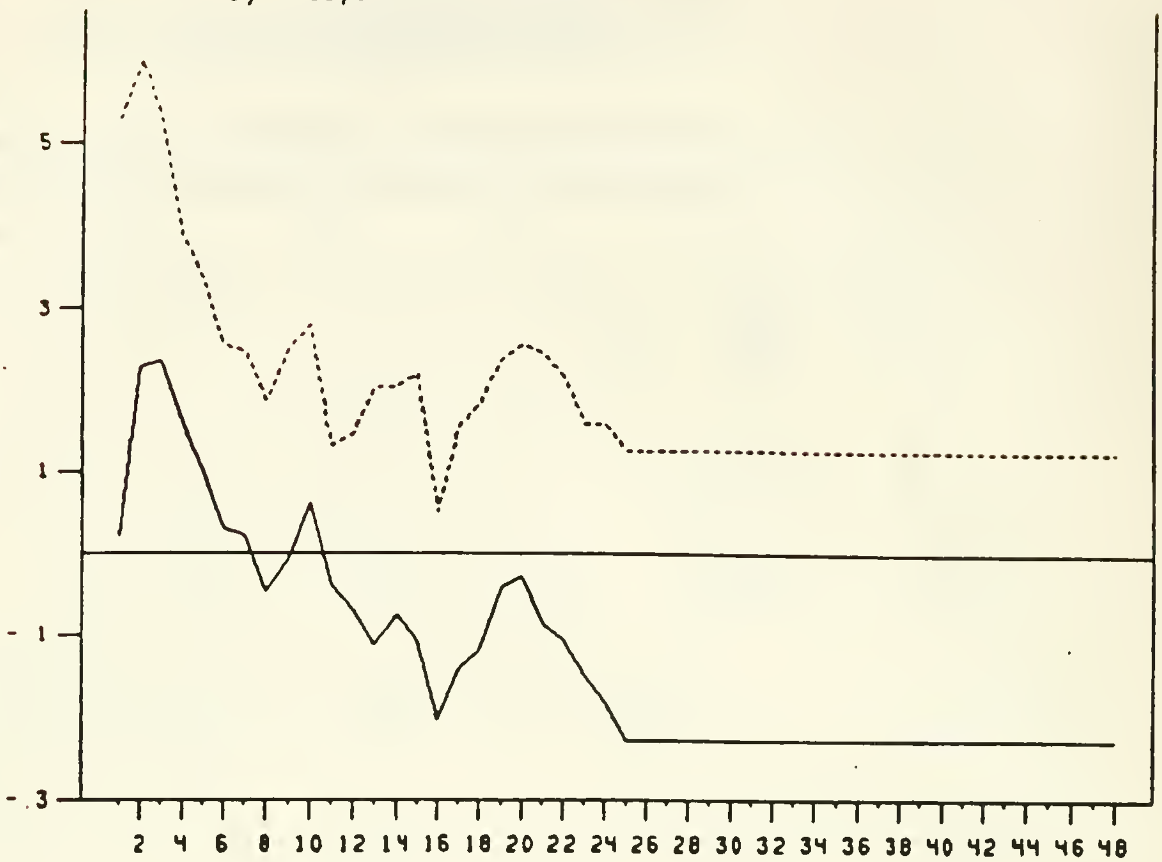
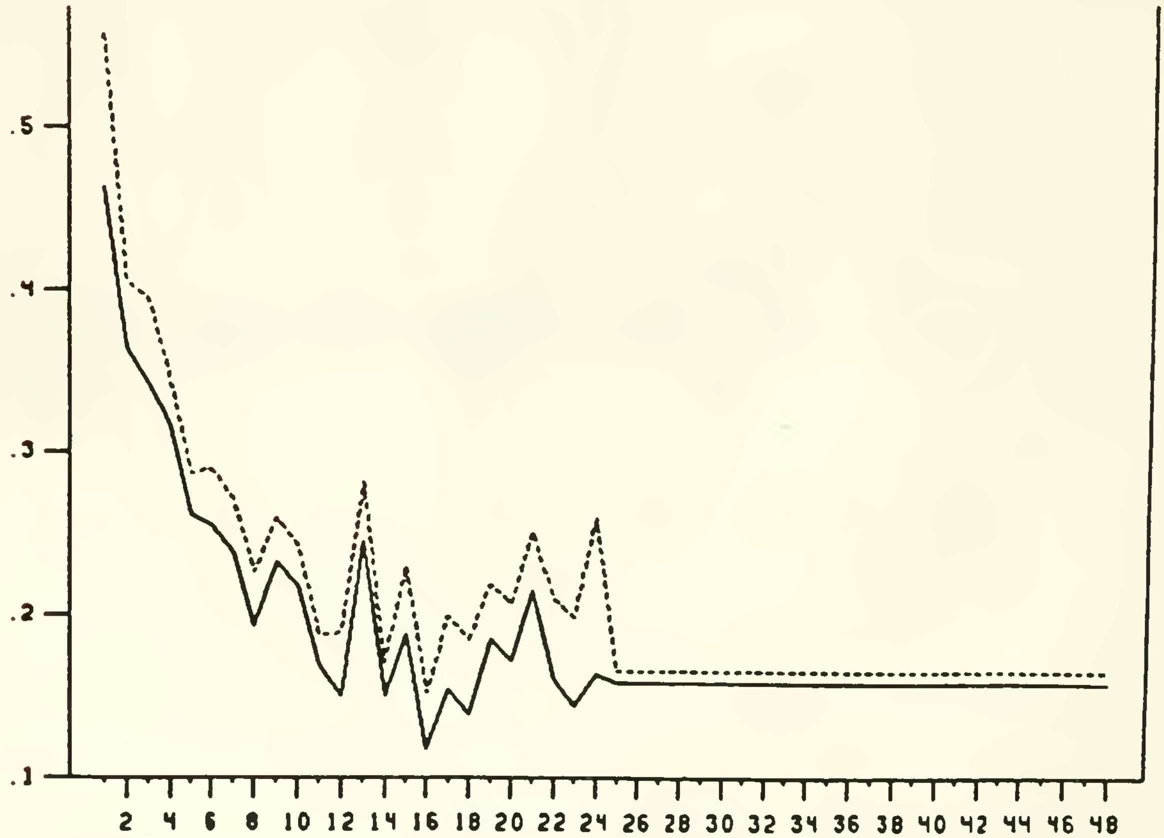


Figure 3
Productivity over Time

a) Response to Manhours



b) Response to Output



Solid lines are for differenced specification, broken lines for levels specification.

APPENDIX
Differentiated Products

Consider monopolistically competitive firms similar to those studied by Dixit and Stiglitz (1977) facing individual demand functions given by:

$$Q = suD(P) \tag{A1}$$

where Q is the quantity demanded and P is the price charged, D is a decreasing function while s and u are again indicators of the state of demand. The level of u in principle depends also on the price charged by other firms in the industry. The state s has a probability density function f(s) with support given by $[s^l, s^u]$. With the same technology as in the main text, profits are given by:

$$\int_{s^l}^{s^u} \min\{Y, usD(P(s))\}[P(s)-c]f(s)ds - vY \tag{A2}$$

where P(s) is the price in state s.

Flexible Prices

Suppose first that prices can be varied from state to state. Optimal prices are then given by:

$$D + D'(P(s)-c) = 0 \tag{A3}$$

if the solution to this equation satisfies $usD(P(s)) \leq Y$ and equal to:

$$usD(P(s)) = Y \tag{A4}$$

otherwise. This is the standard "peak-load" pricing solution. For states up to a critical state s^r, prices are constant and equal to marginal cost c times $\epsilon/\epsilon-1$ where ϵ is the elasticity of demand at

this optimal price. For states above s^r, price is set so that exactly the level of capacity is demanded. It is never worthwhile to set price below the level that clears the market so rationing is never observed.

Given this pattern of pricing, profits are given by:

$$u[c/(\epsilon-1)]D(c\epsilon/(\epsilon-1) \int_{s^l}^{s^r} sf(s)ds + \int_{s^r}^{s^u} Y[D^{-1}(Y/us) - c]f(s)ds - vY \quad (A5)$$

where the first term can be thought of as the difference between revenues and costs in the unconstrained states while the others represent this difference in the constrained states.

Differentiating (A5) with respect to Y we obtain optimal capacity:

$$\int_{s^r}^{s^u} [D^{-1}(Y/us)+D^{-1\prime}Y/us-c]f(s)ds-v=$$

$$\int_{s^r}^{s^u} \{D^{-1}(Y/us)[1-1/\epsilon(P(s))]-c\}f(s)ds-v=0 \qquad (A6)$$

where the elasticity of demand $\epsilon(P(s))$ depends on s because it can depend on P.

This standard peak load pricing model can only account for high prices when there is excess capacity if demand is quite inelastic.

<u>Inflexible Prices</u>

If firms cannot vary prices with the state s, their optimal price is obtained by setting P(s) equal to P in (4) and differentiating

$$[\int_{s^l}^{s^*} sf(s)]u[D+D'(P-c)] + [1-F(s^*)]Y = 0. \qquad (A7)$$

where s^* is the state at which demand is just met and equals $K/uD(P)$. The second order conditions require that this expression be decreasing in P. This implies that the optimal price exceeds the flexible price in the unconstrained states as determined by (A3).

Perhaps surprisingly, increases in capacity raise the optimal price. This is a consequence of the fact that increases in Y raise the importance of the capacity constrained regime in which increases in price are desirable. Note also that it is never optimal to sell Y in all states since, in this case, the derivative of profits with respect to price is strictly positive.

Now consider the optimal choice of capacity itself when prices are constant accross states. Differentiating (A2) with respect to Y and setting to zero (the effect of changes in Y on P can be neglected by the envelope theorem):

$$[1-F(s^*)](P-c) - v = 0. \tag{A8}$$

This expression establishes that, if v is positive, $[1-F(s^*)]$ must be positive as well. So, at least some states must have rationed customers. It is instructive to note that as the elasticity of demand (which is determined by D') approaches infinity, the price charged by the firm approaches c+v which may be thought of as long run marginal cost. Thus the idea that firms price at long run rather than short run marginal cost which makes no sense from the point of view of standard theory is logical if constraints preclude the adjustment of prices to changing demand conditions.

Using the definition of s^* to substitute for Y in (A7) it is apparent that equations (A7) and (A8) give values of P and s^* which

are independent of u. This has several consequences. Suppose first that the number of firms is fixed and think of changes in u as being permanent changes in demand. When capacity adjusts to this change in demand, i.e. in the long run, Y, output and the other inputs all rise proportionately. This means that, while an increase in demand will in the short run raise labor productivity, i.e. there will be short run increasing returns to labor, in the long run labor productivity is constant. In other words, as firms adjust their capacity optimally, labor productivity falls.

Now suppose that there is entry and exit. One way of capturing this entry and exit is via changes in u. When new firms enter, there is less demand for existing firms and u falls. One can imagine that there are also fixed costs of setting up firms and that these adjustments in u take place until there are no profits to be earned in the industry. Note again that these adjustment do not affect either price or the probability of being rationed. So, for instance, if there are large fixed costs of setting up a firm, u will in equilibrium have to be quite large. Each firm will have to sell a large quantity to cover its fixed costs. Note however, that our model is consistent with the absence of any such fixed costs. Constant returns to scale and free entry can coexist with monopolistic competition in the sense that each firm faces a downwards sloping demand.

Explaining Procyclical Productivity

In this section we show that the rigidity of prices across

states s tends to make productivity as measured either using labor's share in costs or its share in total output procyclical in response to changes in u. We start our discussion by showing that, in either case, sales rise in previously unconstrained states when u rises. For the case of flexible prices this is immediate from (A5) since the price in the unconstrained states remains the same and demand increases. The same would be true under fixed prices if prices did not respond to u. We now show that when state noncontingent prices respond optimally to u, sales rise as well.

For total sales not to change prices would have to increase so much that uD, and thus s^*, remain unchanged. Note that the price increases of other firms in response to the increased demand have the effect of raising u further. From (A7) it is apparent that if prices rose by such a large amount, firms would want to lower them. This can be seen as follows. At the original equilibrium [D+D'(P-c)] is negative since $[1-F(s^*)]Y$ is positive. Thus the the increase in u (at an unchanged s^*) lowers the expression in (A7). Moreover any increase in the firm's price has, itself, a negative effect on [D+D'(P-c)]. Therefore such large price increases render the derivative of profits with respect to price negative. Firms raise their price less and total sales increase.

In order to determine whether firms whose price does not depend on s will respond to an increase in u by lowering or raising prices, we differentiate (7) with respect to u at unchanged prices and obtain:

$$\left[\int^{s^*} sf(s)\right][D+D'(P-c)] - s^{*2}D'(P-c).$$

The first term in this expression is negative while the second is positive. Thus the optimal response of prices to changes in demand is ambiguous. If the first term dominates, prices fall instead of rising. The reason for this ambiguity is that, when demand increases, more is sold in the unconstrained states and in these states the derivative of profits with respect to price is negative. On the other hand, as demand increases, there are more states in which the capacity constraint is binding and this promotes increases in price. This provides a possible rationalization for the pro-cyclicality of real wages. If prices fall during expansions, real wages will appear to be pro-cyclical.

With flexible prices sales only increase in the states in which the firm is charging $c\epsilon/(\epsilon-1)$ so that when state contingent prices are used to measure industry output dR/dL is simply $\epsilon/(\epsilon-1)$. So as Hall points out, his measurement of procyclical productivity corresponds to market power in the usual sense of absence of substitutes.

When prices do not vary with s, dR/dL is equal to PdQ/dL where dQ is the total change in output. Moreover, dQ/dL is still equal to $1/c$. Yet, as we mentioned under equation (9), the price exceeds $c\epsilon/(\epsilon-1)$, so that dR/dL exceeds $\epsilon/(\epsilon-1)$. That is, an analyst who in the presence of price inflexibility naively inferred the extent to which firms compete through price or the extent to which firms produce goods with good substitutes from the cyclicality of the Solow residual measured using labor's share in value would understate the importance of competitive forces.

In the constant elasticity case dR/dL equals:

$$\epsilon/\{\epsilon - 1 + [1-F(s^*)]/[\int_{s^1}^{s^*} sf(s)ds]\}$$

As ϵ becomes large, so that conditions become competitive, s^* tends to s^1 so that the difference between dR/dL and $\epsilon/(\epsilon-1)$ rises.

Consider now changes in the capacity costs v keeping k, total marginal cost fixed. For v equal to zero, s^* is infinite and dR/dL is simply $\epsilon/(\epsilon-1)$ while it is clearly larger for positive v. We have not derived necessary conditions for dR/dL to be strictly increasing in v but some tedious algebra establishes that it is true for linear demand and nonconcave F.

A more dramatic contrast highlighting the importance of price rigidities for the study of productivity emerges from a comparison of Solow residuals when these are computed using factor shares in cost rather than factor shares in revenue. Since labor is the only factor of production here, its cost share is one. Thus Solow residuals measured in this way will be procyclical if the naive measure of labor productivity R/L is procyclical. We show that the ratio R/L will be procyclical if prices are rigid while it need not exhibit any cyclical pattern whatever if prices are flexible.

Consider first the case of inflexible prices. Since base period prices do not depend on s the change in revenues over labor input is proportional to the change in physical output per labor input. In particular,

$$(dR/R)/(dL/L) = 1 + v/c[\int sf(s)ds/s^* + (1-F(s^*))] \quad (A9)$$

which clearly exceeds one if v is positive. From (A7) it is apparent that if there is no quasi-fixed labor (v is zero), productivity is not cyclical while if all costs are congealed (c is

zero) $(dR/R)/(dL/L)$ is infinite. It can be shown that, at least for the case of linear demand, $(dR/R)/(dL/L)$ monotonically increases with v as long as k is kept constant.

Let us now consider the case of flexible prices. We show that, in the presence of peak-load pricing, the ratio of the value of output (at base prices) to labor input need not be procyclical even when there is some labor fixity in the short run. This result is analogous to Hall's (1987) conclusion that under constant returns to scale and optimal capacity choice the Solow residual using shares in cost should be acyclical. Our result differs somewhat in that, for our cost function, the variability in prices across states within the period used for mesuring revenue and labor input is crucial for the result while this variability is inessential for the cost functions employed in Hall (1987).

We have already shown that dR/dL equals $\epsilon/(\epsilon-1)$. Labor productivity will be procyclical if R/L is smaller than this, countercyclical if it bigger. From the analysis of (A5):

$$R = u[c\epsilon/(\epsilon-1)]D(c\epsilon/(\epsilon-1)\int_{s^l}^{s^r} sf(s)ds + \{\int_{s^r}^{s^u} Y[D^{-1}(Y/us)f(s)ds\}$$

$$L = ucD(c\epsilon/(\epsilon-1)\int_{s^l}^{s^r} sf(s)ds + \{\int_{s^r}^{s^u} Ycf(s)ds + vY\}$$

where revenues and costs in the unconstrained states are given by the first terms in each expression while the terms in curly brackets apply to the constrained states. Not surprisingly the ratio of the first terms is $\epsilon/(\epsilon-1)$. From (A6) it is also apparent that the ratio of the terms in curly brackets (at the point at which capacity is chosen optimally) is also $\epsilon/(\epsilon-1)$. Therefore, in the constant

elasticity case, R/L equals $\epsilon/(\epsilon-1)$ and productivity is independent of u. Suppose that, instead of being constant, the elasticity of demand falls as s increases. This would occur if the elasticity of demand fell when price rises (as would be the case if D(P) were linear). The ratio of revenues to costs is then larger in the constrained region and productivity is countercyclical. The opposite is true if the elasticity of demand is high when demand is high.

The basic intuition behind the result that labor hoarding is insufficient, without rigid prices, to generate procyclical movements in R/L is the following. With perfect peak-load pricing the only states in which output rises are the excess capacity states. While in these states price is above marginal cost, it is still low relative to price in the constrained states. Therefore, there is no presumption that revenues will rise more than in proportion to labor input when output is increased in these states.